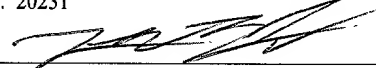


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**System and Method for Configuring a GUI Element  
to Publish or Subscribe to Data**

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## Field of the Invention

The present invention relates to the field of computer program data exchange, and more particularly to a system and method for configuring a graphical user interface (GUI) element to publish or subscribe to data, e.g., to send data associated with the GUI element to a data target or to receive and display data from a data source.

## Description of the Related Art

Graphical user interfaces (GUIs) enable users to interact with computer programs in an intuitive manner, utilizing various types of graphical user interface (GUI) elements.

Different programming environments may enable developers to include any of various types of GUI elements in a program's graphical user interface. For example, Figures 1 and 2 (prior art) illustrate several GUI elements, including GUI elements that may be used in instrumentation or measurement applications. Figure 1 (prior art) illustrates an exemplary graphical user interface panel for a measurement program for computing the averaged power spectrum of a simulated input signal. For example, the panel includes a knob GUI element for adjusting the frequency of the simulated signal and a chart GUI element for displaying a chart of the power spectrum. Figure 2 (prior art) illustrates additional examples of GUI elements useful for instrumentation or measurement applications, e.g., a thermometer, an LED, a meter, a waveform chart, a tank, etc. Other types of GUI elements that may be included on a graphical user interface panel include text boxes, check boxes, etc.

GUI elements may be configured to indicate data to the user, e.g., by displaying the data on a display screen. For example, the Power Spectrum chart on the user interface panel of Figure 1 displays a chart of the averaged power spectrum computed by the program.

In many cases, it may be desirable for data indicated by a GUI element to originate from a data source outside of the program. For example, in various applications, it may be desirable for the data to originate from a file, such as a file on the host computer system or a file received from a remote computer server, such as an FTP or

HTTP server. It may also be desirable for the data to originate from another program or process running on the host computer system or a remote computer system. For example, an application for viewing live weather data may display data received from a remote computer system that senses weather-related variables, such as temperature, wind speed, humidity, etc., and transduces these variables into data that the application can display. It may also be desirable for the data indicated or displayed by a GUI element to be provided to a data target outside of the program.

GUI elements may also be configured to provide user input to a program. For example, when the value of the Frequency knob on the user interface panel of Figure 1 changes, e.g., due to a user interactively turning the knob, the program may detect this change in value, e.g., by intercepting an event triggered when the value changes, and may respond by changing the signal that is generated in accordance with the new frequency value.

In many cases, it may be desirable for user input received by a GUI element to be provided to a data target outside of the program. For example, a program to control a system located in a remote laboratory may have a graphical user interface panel including various GUI elements such as knobs, buttons, etc. When a user changes the values associated with the GUI elements, it may be desirable for the program to send the values to a program running on a computer system in the remote laboratory which is operable to send control signals to the system, based on the received GUI element values. It may also be desirable for an input GUI element to receive input data from a data source.

In the prior art, developing a program which associates a GUI element with an external data source or target is often a difficult and time-consuming task. For example, consider the program described above for viewing weather data, wherein a client computer system that executes the viewer program is connected over a TCP/IP network to a server computer that generates the data. In order for the viewer program to receive the data from the server computer, the TCP protocol would typically be used, which may involve several steps, such as:

- choosing a TCP/IP port number not in use by any other applications

- defining the application-level protocol (e.g., what gets sent when)
- configuring the server computer to listen on the selected port and create a connection when the viewer program initiates a request
- configuring the server computer to marshal the data and write to all connections
- 5 • configuring the viewer program to connect to the selected port and unmarshal the data
- managing any errors

This list only provides an overview of the complexity involved in receiving the data. Once the data is received, the developer must still associate the data with the GUI  
10 element such that the data is displayed properly. Thus, this scenario illustrates several details that many developers would not have the necessary skill to deal with or would prefer not to deal with.

A further disadvantage of the prior art is that a consistent mechanism for associating GUI elements with different types of data sources and targets is lacking. For  
15 example, reading data from a file instead of a remote server may require the developer to code a different set of steps, e.g., to open the file, read data from the file, close the file, etc.

Thus, associating a GUI element with different types of data sources or targets may require different types of expertise. The situation is further complicated when  
20 platform issues are considered. For example, different computing platforms support different mechanisms for data exchange. For example, a Windows program may use DDE or ActiveX/COM, whereas programs running on other platforms use different mechanisms.

Thus, an improved system and method for associating a GUI element with a data  
25 source and/or target are desired. As described above, this task can be difficult and time-consuming, and some users may not possess the necessary knowledge required, especially those users who are not highly trained in programming techniques.

Thus, it would be highly beneficial if the system and method were to enable the user to configure a GUI element to publish data to a data target and/or subscribe to data

from a data source without requiring the user to specify any source code. It would be also desirable for such an improved system and method to be independent of the type of data source or target. For example, the method of configuring a chart GUI element to display waveform data read from a file would ideally be the same or substantially the same as the  
5 method of configuring the chart GUI element to display live waveform data generated by a remote application. It would be also desirable for such an improved system and method to be independent of the platform on which the program runs.

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## Summary of the Invention

One embodiment of the present invention comprises a system and method for configuring a graphical user interface (GUI) element to publish data to a data target and/or subscribe to data from a data source. During program development, a developer may  
5 associate a GUI element with a program or otherwise cause a GUI element to be displayed.

The GUI element may be for receiving user input data or indicating data to the user. The GUI element may be an element of any of various types, e.g., depending on which GUI elements are supported by an application development environment that the developer uses to create the program. For example, various application development environments may  
10 support GUI elements such as graphs, text boxes, check boxes, knobs, etc. The application development environment may also enable the developer to create or use custom GUI elements. For example, some application development environments enable developers to use custom GUI elements packaged as ActiveX controls.

The GUI element (or a set of GUI elements) may be associated with the program in  
15 various ways, e.g., depending on the particular application development environment or programming language. Typically, the developer creates a graphical user interface panel and places various GUI elements on the panel, e.g., by choosing the GUI elements from a palette, from menu options, from a dialog box, etc.

The developer may then configure the GUI element to publish data associated with  
20 the GUI element to a data target and/or to subscribe to data from a data source. In the preferred embodiment, the developer is not required to specify any source code for the program in performing this configuration. For example, the developer may simply invoke a dialog box and choose from a set of options, such as "Publish", "Subscribe", and "Publish and Subscribe" in order to specify a data connection type for the GUI element. The  
25 developer may also specify a data source or target for the data connection, e.g., by specifying a uniform resource locator (URL).

In the preferred embodiment, the developer may specify various types of data sources/targets for the data connection. The type of data source/target may be specified by the access method portion of a URL. For example, a URL such as

“http://www.ni.com/data.html” specifies an HTTP server, while a URL such as “ftp://www.ni.com/data.txt” specifies an FTP server. In one embodiment, supported data sources/targets include: files, HTTP servers, FTP servers, OPC servers, SNMP servers, and a type of server referred to herein as a “DataSocket” server. In other embodiments, any of various other data source/target types may be supported.

Once the developer has created the GUI element and configured the GUI element with a data connection to a data source and/or target, the GUI element may be operable to automatically begin publishing data or subscribing to data. Alternatively, if the GUI element is comprised in a program, the GUI element may publish and/or subscribe to data when the program is executed. During program execution, the program may be operable to automatically, i.e., programmatically, determine and use an appropriate protocol for interfacing with the data source/target, such as HTTP, FTP, SNMP, etc.

If the developer configured the GUI element to subscribe to data from a data source, then the program may connect to or open the data source, using an appropriate protocol or access method, and receive data from the data source. This data may then be provided to the GUI element. If the GUI element is an input GUI element, the GUI element may be operable to receive and display the input data and provide the input data to other parts of the program. If the GUI element is an output GUI element, the output GUI element may be operable to display or otherwise indicate the received data to the user. The GUI element may indicate the data in various ways, e.g., depending on the type of data and/or the GUI element type. The data is typically displayed on a display screen, but may also be indicated in other ways, e.g., as audio.

Any of various types of data may be associated with a data source, such as strings, scalars, Booleans, waveforms, etc. A given GUI element may only be operable to receive or indicate certain types of data. For example, a chart GUI element may be able to display two-dimensional numeric waveform data, but not three-dimensional waveform data. In this case, if three-dimensional waveform data is received from a data source with which the chart GUI element is associated, an invalid data connection may be indicated, e.g., by displaying a small colored indicator beside the GUI element. In one embodiment, data may

be received in a self-describing format enabling the program (or execution environment) to parse the data appropriately and determine whether the data is valid data for a particular GUI element. In one embodiment, if the data is not valid data for the GUI element, then the program or execution environment may be operable to dynamically select a GUI element  
5 that is valid for the data, i.e., a GUI element that can receive and display the data. This GUI element may then be dynamically substituted for the original GUI element, such as at execution time.

If the developer configured the GUI element to publish data to a data target, then the program may connect to or open the data target, using an appropriate protocol or access  
10 method, and send or write data associated with the GUI element to the data target. For example, data may be associated with the GUI element programmatically. In other words, a computer program may operate to generate data during program execution and provide the data to the GUI element, such as for display. In the prior art GUI of Figure 1, for example, the program includes source code to programmatically specify power spectrum data for the  
15 Power Spectrum chart to display. Thus, the developer could easily configure the Power Spectrum chart to publish the power spectrum data to a data target, e.g., to provide the data to a remote application or write the data to a file.

In other cases GUI element data to be published to a data target may be received as user input. In the prior art GUI of Figure 1, for example, a data value for the Frequency  
20 knob GUI element is received as user input. Thus, the developer could easily configure the knob to publish the input frequency value received from the user to a data target, e.g., to control a remote system operable to receive the frequency value from this data target or to allow a remote user to view the input data being provided to the program.

In one embodiment, the developer may configure a GUI element to both publish and  
25 subscribe to data. For example, the developer could configure a knob GUI control, such as the Frequency knob shown in the GUI of Figure 1, to publish and subscribe to data. For example, consider a situation in which two control programs execute at different locations, wherein both control programs monitor a remote system and control the opening and closing of a valve in the remote system. A knob GUI control for each program may display



a value indicating a setting for the remote system valve. If a user of one of the control programs, i.e., the “first” control program, turns the knob, then the first control program may send a control message to the remote system, causing the remote system to adjust the valve setting accordingly. The first control program may also publish the new knob setting  
5 value to a data target/source, such as a server, to which the knob GUI control of the first control program is configured to publish and subscribe. The other control program, i.e., the “second” control program, may also subscribe and publish to this data source/target, so that the change in the knob setting is automatically reflected on the GUI of the second control program. Since both control programs publish and subscribe to the data source/target, a  
10 change in the GUI knob control setting that originates from the second control program will similarly be automatically reflected on the GUI of the first control program.

The scenario described above is one example of exchanging “live” data between different applications. In this case, data may be exchanged only periodically, e.g., when a user turns a knob GUI control on one of the control programs. In other cases, live data may  
15 be exchanged continuously. Other examples of live data exchange include: a reader application that subscribes to live multimedia data, e.g., audio and/or video data, generated by a writer application; two chat programs that exchange live text data with one another; etc. Also, as measurement and automation applications have become increasingly distributed and software-oriented, live data exchange has become especially important in  
20 these applications, e.g., in order to send acquired or generated signals across a network.

In various embodiments, the live data exchange may be implemented in any of various ways. In one embodiment, a server program or process may act as an intermediate between a writer program that writes live data and a reader program that subscribes to the live data. In one embodiment, multiple reader programs may receive and display data  
25 generated by a writer program, by interfacing with the server. For example, multiple users may execute a reader program to view live weather data. In the prior art, creating these types of applications is typically a complicated task, but one embodiment of the present invention enables data exchange between a writer program and multiple reader programs

executing in different locations to occur without the developer having to specify or write any source code to accomplish the data exchange.

Programs having GUI elements configured as described above may be implemented using any of various programming languages or application development environments. The GUI elements may also be associated with any of various programming tools or development environments. In one embodiment, the programs which include the GUI elements may be graphical programs. Graphical programming has become a popular programming paradigm, especially among scientists and engineers. In creating a graphical program, a developer may include a plurality of graphical nodes and other graphical elements on block diagram and connect the nodes and elements such that the resulting diagram graphically represents the functionality of the graphical program. The graphical nodes or icons may be connected using one or more of data flow, control flow, and/or execution flow techniques. Many developers find graphical programming to be a more intuitive and user friendly model for developing a program, e.g., as opposed to using a traditional text-based programming language, such as C, C++, Basic, etc. Thus, one embodiment of the present invention further enhances the user-friendliness of graphical programming by enabling a developer to easily configure a data connection for a GUI element on a graphical program's graphical user interface panel.

In one embodiment, a program with a GUI element configured with a data connection to a data source or target may utilize a separate layer or component for interfacing with the data source or target. One embodiment of such a layer, referred to as "DataSocket", is described. DataSocket provides a single, unified, end-user application programming interface (API) for connecting to data from a number of sources, such as local files, files on FTP or Web servers, and data items on OPC Servers. A DataSocket application specifies the data location by using a familiar networking standard, the URL. Just as a Web browser uses a URL to connect to a Web page, a DataSocket application uses a URL to connect to data. In addition, the DataSocket Transfer Protocol connects a DataSocket application to live data by specifying a connection to a DataSocket Server. The DataSocket Server manages most of the networking tasks for the developer.

With conventional technologies such as TCP/IP, the developer would have to write code to convert data to an unstructured stream of bytes in the broadcasting application, as well as code to parse the stream of bytes back into its original form in subscribing applications. DataSocket, however, transfers data in a self-describing format that can represent data in an unlimited number of formats, including strings, scalars, Booleans, and waveforms. The DataSocket read and write operations transparently convert data to and from the underlying byte streams, eliminating the need to write complicated parsing code. DataSocket uses a protocol referred to as the DataSocket Transport Protocol (DSTP) to send data to and receive data from a DataSocket server.

As described above, many applications require data to be exchanged with various types of data sources and targets, but this data exchange is often a difficult task for developers. Thus various embodiments of the system and methods described above may greatly benefit users by enabling complicated exchange of data to be performed by a simple configuration of a GUI element for a program.

In the above description, the program developer may first include a GUI element in the program's graphical user interface and may then configure the GUI element with a data connection to a data source. In another embodiment, the developer may first specify a data source, e.g., via a URL, and the method may automatically or programmatically determine an appropriate GUI element to display data received from the data source, automatically include the GUI element in the program's GUI, and automatically configure the GUI element to display data from the data source when the program is executed. Various techniques for automatically determining an appropriate GUI element are described. For example, the method may connect to the data source to receive a data sample and may examine the received data to determine an appropriate GUI element.

In one embodiment, the decision of which GUI element to include in the program's GUI may be deferred until the program is executed, or a first GUI element may be selected and the GUI element may be changed to a new type during program execution. For example, it may not be possible to connect to the data source during

program development. Also, the type of data associated with the data source could change from development time to runtime. Thus, in these cases it may be desirable to examine the data at runtime and select an appropriate GUI element dynamically or programmatically. The GUI element may then be dynamically included in the program's graphical user interface and configured to display the received data.

One embodiment of the invention comprises a program which utilizes this ability to dynamically or programmatically select a GUI element in order to enable end users to connect to various types of data sources and display data received from the data sources. In such a program, an end user (i.e., a user of the program, rather than the program developer) may specify a data source. The data source may be a data source of any of various types, such as a file or a server of various types, such as an HTTP server, an FTP server, an OPC server, an SNMP server, a DataSocket server, a database server, etc. The end user may specify the data source in any of various ways. For example, the program may be operable to receive URL information specifying the data source, similarly as described above.

In response to receiving the data source information from the end user, the program may be operable to automatically determine an appropriate GUI element for displaying data from the data source, display the GUI element, and provide data from the data source to the GUI element for display. The appropriate GUI element may be determined similarly as described above, e.g., by connecting to the data source to receive a data sample from the data source and then examining the received data, or in any of various other ways. Also, in one embodiment, the program may enable the user to explicitly specify a GUI element to use in viewing the data. For example, in response to a user command, the program may display a set of GUI elements from which the user can choose.

Thus, as previously described, one embodiment of the invention enables a program developer to develop a program which, when executed, is operable to display data from a particular data source, wherein, in developing the program, the program developer is able to simply display a GUI element and specify a data source URL with which to associate the GUI element, without having to program the functionality of interfacing with the data source. Another embodiment of the invention enables the implementation of a program

which, when executed, enables an end user to specify a data source, e.g., via a URL, and view data received from the data source, wherein the end user may specify any of various types of data sources and any of various types of data may be received from the data sources. In this embodiment, one of various types of GUI elements is dynamically, i.e., programmatically, selected and displayed to allow the end user to view the received data. Thus, the end user may only be required to specify the data source, and selection, display, and configuration of the GUI element to subscribe to the data may be performed automatically or programmatically.

This latter embodiment may be utilized, for example, to implement a data viewer tool which end users may execute to view various types of live data. For example, the data viewer tool may enable end users to connect to remote instrumentation systems and view real-time data acquired or generated by the systems, including numeric data, two-dimensional waveform data, three-dimensional waveform data, etc.

15

## Brief Description of the Drawings

A better understanding of the present invention can be obtained when the following detailed description of the preferred embodiment is considered in conjunction  
5 with the following drawings, in which:

Figures 1 and 2 (prior art) illustrate several GUI elements, including GUI elements that may be used in instrumentation or measurement applications;

10 Figures 3A and 3B illustrate exemplary networked computer systems;

Figures 4A and 4B illustrate representative instrumentation and process control systems including various I/O interface options;

15 Figure 5 is an exemplary block diagram of the computer systems illustrated in Figures 4A and 4B;

Figure 6 is a flowchart diagram illustrating one embodiment of a method for creating and executing a program including a GUI element configured to receive data  
20 from a data source and indicate the data to the user;

Figure 7 is a flowchart diagram illustrating one embodiment of a method for receiving user input specifying a data source with which to associate a GUI element;

25 Figure 8 illustrates a popup menu displayed by right-clicking on a GUI element, which may be used to invoke a dialog box for specifying data connection information for the GUI element;

Figure 9 illustrates an exemplary dialog box for specifying data connection information for a GUI element, wherein the user has chosen a “Subscribe” option specifying that the GUI element should subscribe to data from a data source;

5        Figure 10 is a flowchart diagram illustrating one embodiment of a method for creating and executing a program including a GUI element configured to publish data to a data target;

10        Figure 11 illustrates the dialog box of Figure 9, wherein the user has chosen a “Publish” option specifying that the GUI element should publish data to a data target;

15        Figure 12 is a flowchart diagram illustrating one embodiment of a method for exchanging data between a writer and a reader program, wherein the program developer(s) is not required to specify any source code to perform this data exchange;

20        Figures 13 and 14 illustrate graphical user interface panels for a writer program and a reader program, respectively, wherein each GUI panel includes a chart GUI element configured with a data connection;

25        Figure 15 illustrates one embodiment of a graphical program block diagram corresponding to the reader program GUI panel illustrated in Figure 14;

      Figure 16 illustrates one embodiment of a graphical program block diagram corresponding to the writer program GUI panel illustrated in Figure 13;

      Figure 17 illustrates another embodiment of a graphical program block diagram corresponding to the reader program GUI panel illustrated in Figure 14;

Figures 18 illustrates the dialog box of Figure 9, in which the user utilizes a browse feature to choose a data source or target;

Figure 19 illustrates a dialog box enabling the user to select from various data sources and targets associated with hardware instruments connected to the computer;

Figure 20 illustrates an alternative embodiment of a dialog box for specifying data connection information;

Figure 21 illustrates a status indicator that appears beside a GUI element when a data connection for the GUI element has been specified, wherein the status indicator indicates the status of the data connection;

Figures 22 – 23 illustrate GUI panels for a writer program and reader program, respectively, wherein the writer program displays and writes 3D waveform data to a server and the reader program receives and displays this 3D data;

Figure 24 illustrates a GUI panel for a program operable to receive and display live weather data, such as wind speed data, temperature data, humidity data, etc., wherein the developer displays a popup menu to configure a data connection for a GUI element on the GUI panel;

Figure 25 is a flowchart diagram illustrating one embodiment of a method for performing two-way data exchange between two programs by configuring a GUI element in each program to publish and subscribe to a data target/source;

Figure 26 illustrates an example of a DataSocket server receiving data from a single writer application and providing the data to a plurality of reader applications;



Figure 27 is a block diagram illustrating a communication protocol referred to as the DataSocket Transport Protocol (DSTP);

Figures 28A – 28B are a flowchart diagram illustrating the Connect method of a DataSocket; and

Figure 29 is a flowchart diagram illustrating one embodiment of a method for enabling an end user to view various types of data from various types of data sources.

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While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

## Detailed Description of the Preferred Embodiments

### Incorporation by Reference

5 The following patent applications are hereby incorporated by reference in their entirety as though fully and completely set forth herein:

U.S. Patent Application Serial No. 09/185,161 titled, "DataSocket System and Method for Accessing Data Sources Using URLs" filed on November 3, 1998, whose inventor was Paul Austin;

10 U.S. Patent Application Serial No. 09/374,740 titled, "System and Method for Automatically Creating URLs for Accessing Data Sources and Data Targets" filed on August 13, 1999, whose inventors were Paul F. Austin, David W Fuller, Brian H. Sierer, Kurt Carlson, Stephen Rogers and Chris Mayer; and

15 U.S. Patent Application Serial No. 09/518,492 titled, "System and Method for Programmatically Creating a Graphical Program," filed on March 3, 2000, whose inventors were Ram Kudukoli, Robert Dye, Melanie Jensen, and Yumiko Kawachi.

U.S. Patent Application Serial No. 09/546,047 titled, "System and Method for Connecting to and Viewing Live Data using a Standard User Agent," filed on April 10, 2000, whose inventor was Paul F. Austin.

20 U.S. Patent Application Serial No. \_\_\_\_\_ titled, "System and Method for Automatically Configuring Program Data Exchange," filed on \_\_\_\_\_, whose inventors were \_\_\_\_\_.

U.S. Patent Application Serial No. \_\_\_\_\_ titled, "System and Method for Automatically Configuring a Graphical Program to Publish or Subscribe to Data," filed on \_\_\_\_\_, whose inventors were \_\_\_\_\_.

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### Figures 3A and 3B – Computer Systems Connected Via a Network

One embodiment of the present invention enables developers to easily create programs that exchange data with each other, including programs that execute on separate

computer systems. Figures 3A and 3B illustrate exemplary networked computer systems. It is noted that Figures 3A and 3B are exemplary only and that, in various embodiments, the present invention may be used in any type of system, including a system with only one computer.

5           Figure 3A illustrates an exemplary system in which a first computer system 82 is connected through a network 84 to a second computer system 86, and the second computer system 86 is connected through a network 88 to a third computer system 90. The computer systems 82, 86, and 90 can be any of various types, as desired. The networks 84 and 88 can also be any of various types, including the Internet, a LAN (local area network), or a WAN  
10 (wide area network), among others. The networks 84 and 88 may also be the same network.

          In one embodiment, the first computer system 82 may execute a writer program that generates data, and the third computer system 90 may execute a reader program that uses the data generated by the first computer system 82. The computer system 86 may act as an  
15 intermediate server between the writer program and the reader program. For example, the intermediate server 86 may execute a server program (or process) with which the writer program and the reader program interface in order to exchange data. One embodiment of such a server program, referred to herein as a "DataSocket server," is described below.

          Such an intermediate server program may not necessarily execute on a separate  
20 computer system from the writer and reader programs. For example, the computer system 82 may execute the writer program which may interface with a server program also executing on the computer system 82. In this case, a reader program may interface with the server program executing on the computer system 82 in order to receive the data generated by the writer program. For example, the reader program may execute on the computer  
25 system 90, e.g., as shown in Figure 3B, or may execute on the same computer system 82. Alternatively, the writer program may execute on the computer system 82, and the server and reader programs may execute on the computer system 90.

          The reader program may include a graphical user interface (GUI) with a GUI element which the developer configured to subscribe to a data target to which the writer

program writes data. In other words, the data target for the writer program may be a data source for the reader program. As described below, one embodiment of the present invention enables the developer to easily associate a GUI element with a data source, without having to specify or write any source code. The GUI element may indicate data  
5 received from the data source, e.g., by displaying the data in various ways.

The writer program may include a graphical user interface (GUI) with a GUI element which the developer configured to publish data to a data source from which the reader program receives data. In other words, the data source for the reader program may be a data target for the writer program. As described below, one embodiment of the present  
10 invention enables the developer to easily associate a GUI element with a data target, without having to specify or write any source code.

It is noted that the writer and reader program do not necessarily both have GUI elements configured as described above. For example, the writer program may include user-specified (i.e., developer-specified) source code to implement writing the data to the  
15 data target, rather than having a GUI element configured to publish data to the data target with no user-created source code required.

It is noted that the use of terms such as “user-specified” and “user input” may vary somewhat in the present disclosure. As described in the summary above, in various embodiments, the invention may be utilized during development of a computer program,  
20 e.g., to aid a developer to create a desired program, or may be implemented in an existing program, e.g., to enable an end user to execute the existing program to view data received from various types of data sources. In the first instance, “user input” may refer to input received from the program developer, such as input received by an application development environment during editing of a program. In the second instance, “user input” may refer to  
25 input received from an end user during execution of an existing program which implements an embodiment of the invention.

In a case where the writer program has a graphical user interface with a GUI element that displays the data that needs to be written to the data target, enabling the developer to simply configure the GUI element to automatically publish the data to the data

target may be a very easy way to write the data to the data target. However, the writer program may not have a graphical user interface or may not display the data in a GUI element. For example, the reader program may receive data from a writer program executing on an embedded device that acquires real-time data from a physical system. In  
5 such a case, the writer program may include explicit source code to write the data to the data target.

Similarly, the reader program may include user-specified (i.e., developer-specified) source code to implement receiving the data from the data source, rather than having a GUI element configured to subscribe to the data source with no user-created source code  
10 required. For example, the reader program may not include a graphical user interface or may not indicate the data received from the data source to the user.

Thus, one or both of a writer program and reader program may implement one embodiment of the present invention, and each of the writer program and reader program may interface with various applications or programs which can publish or subscribe to data  
15 over a network but which do not utilize the present invention.

To illustrate one example of a writer and reader program, consider a writer program executing on a computer system in a laboratory, wherein the writer program is operable to continuously acquire signal data from a hardware unit under test. The writer program may publish the acquired signal data to a data target, such as a server.

20 In one case, the writer program may have a graphical user interface panel that includes a GUI element for displaying the signal data, such as a chart GUI element operable to display the signal data as a two-dimensional waveform. In this case, the developer of the writer program may easily configure the writer program to publish the signal data to the data target by simply associating the chart GUI element with the data target, according to  
25 one embodiment of the present invention. For example, as described below, the developer may simply invoke a user interface dialog box and specify a URL referencing the desired data target for the chart GUI element. In response, the chart GUI element may be automatically, i.e., programmatically, configured to provide the signal data to the data target during execution of the writer program. Thus, the developer of the writer program may not

need to specify or write any source code to accomplish the publication of the signal data to the data target.

In other cases, the writer program may publish the signal data to the data target in other ways. For example, the developer of the writer program may manually create source code to accomplish the publication of the signal data. Also, in other cases, the writer program may not have a GUI element that displays the signal data or may not even have a graphical user interface.

In this example, a reader program may be operable to subscribe to the data target, e.g., the server, to which the writer program publishes the signal data. In other words, the data target for the writer program is a data source for the reader program.

In one case, the reader program may have a graphical user interface panel that includes a GUI element for displaying the signal data acquired from the data source/target, such as a chart GUI element operable to display the signal data as a two-dimensional waveform. For example, a user may execute the reader program in a remote computer system outside of the laboratory, in order to remotely monitor the hardware unit under test.

The developer of the reader program may easily configure the reader program to subscribe to and display the signal data by simply associating the chart GUI element with the data source (i.e., the data target of the writer program), according to one embodiment of the present invention. For example, as described below, the developer may simply invoke a user interface dialog box and specify a URL referencing the desired data source with which to associate the chart GUI element of the reader program. In response, the chart GUI element may be automatically, i.e., programmatically, configured to acquire the signal data from the data source during execution of the reader program and display the signal data. Thus, the developer of the reader program may not need to specify or write any source code to accomplish the acquisition and display of the signal data.

In other cases, the reader program may acquire the signal data from the data source in other ways. For example, the developer of the reader program may manually create source code to acquire the signal data. Also, in other cases, the reader program may not have a GUI element that displays the signal data or may not even have a graphical user

interface. For example, the reader program may acquire the signal data and log the data to a file, without displaying it.

It is noted that various embodiments of the present invention do not use a writer and reader program together such as described above. A writer and reader program may be used together, for example, when “live” data needs to be exchanged between two applications. However, some programs may need to receive data from or write data to a data source/target not associated with another program, such as a file, or other type of data source/target, such as a hardware device. For example, a program may include a GUI element to automatically (i.e., with no explicit source code required) receive data from a file and display the data. Another program may include a GUI element to automatically (i.e., with no explicit source code required) write data associated with the GUI element to a file. In these types of cases a GUI element of a writer or reader program executing on the host computer system 82 may be configured to write data to or read data from a data target or source located either on the host computer system 82 or on another computer system connected via a network, such as computer system 90. Thus, embodiments of the invention may be used with “live” and/or “non-live” data.

#### 20 Figures 4A and 4B - Instrumentation and Industrial Automation Systems

Figures 4A and 4B illustrate an exemplary computer 102 having various types of instruments or hardware devices connected. In various embodiments, the computer 102 may be any of the computers 82, 86, or 90 discussed above. For example, a writer program may execute on the computer 102 and may write data acquired from a connected hardware device to a data target. It is noted that Figures 4A and 4B are exemplary only, and in alternative embodiments, writer and/or reader programs such as described herein may execute on any of various types of systems and may be used in any of various applications.

Figure 4A illustrates an instrumentation control system 100. The system 100 comprises a host computer 102 which connects to one or more instruments. The host

computer 102 comprises a CPU, a display screen, memory, and one or more input devices such as a mouse or keyboard as shown. The computer 102 connects through the one or more instruments to analyze, measure, or control a unit under test (UUT) or process 150.

The one or more instruments may include a GPIB instrument 112 and associated  
5 GPIB interface card 122, a data acquisition board 114 and associated signal conditioning circuitry 124, a VXI instrument 116, a PXI instrument 118, a video device 132 and associated image acquisition card 134, a motion control device 136 and associated motion control interface card 138, and/or one or more computer based instrument cards 142, among other types of devices.

10 The GPIB instrument 112 is coupled to the computer 102 via the GPIB interface card 122 provided by the computer 102. In a similar manner, the video device 132 is coupled to the computer 102 via the image acquisition card 134, and the motion control device 136 is coupled to the computer 102 through the motion control interface card 138. The data acquisition board 114 is coupled to the computer 102, and may interface through  
15 signal conditioning circuitry 124 to the UUT. The signal conditioning circuitry 124 preferably comprises an SCXI (Signal Conditioning eXtensions for Instrumentation) chassis comprising one or more SCXI modules 126.

The GPIB card 122, the image acquisition card 134, the motion control interface card 138, and the DAQ card 114 are typically plugged in to an I/O slot in the computer 102,  
20 such as a PCI bus slot, a PC Card slot, or an ISA, EISA or MicroChannel bus slot provided by the computer 102. However, these cards 122, 134, 138 and 114 are shown external to computer 102 for illustrative purposes.

The VXI chassis or instrument 116 is coupled to the computer 102 via a VXI bus, MXI bus, or other serial or parallel bus provided by the computer 102. The computer 102  
25 preferably includes VXI interface logic, such as a VXI, MXI or GPIB interface card (not shown), which interfaces to the VXI chassis 116. The PXI chassis or instrument is preferably coupled to the computer 102 through the computer's PCI bus.

A serial instrument (not shown) may also be coupled to the computer 102 through a serial port, such as an RS-232 port, USB (Universal Serial bus) or IEEE 1394 or 1394.2



bus, provided by the computer 102. In typical instrumentation control systems an instrument will not be present of each interface type, and in fact many systems may only have one or more instruments of a single interface type, such as only GPIB instruments.

The instruments are coupled to the unit under test (UUT) or process 150, or are  
5 coupled to receive field signals, typically generated by transducers. The system 100 may be used in a data acquisition and control application, in a test and measurement application, a process control application, or a man-machine interface application.

Figure 4B illustrates an exemplary industrial automation system 160. The industrial  
10 automation system 160 is similar to the instrumentation or test and measurement system 100 shown in Figure 4A. Elements which are similar or identical to elements in Figure 4A have the same reference numerals for convenience. The system 160 comprises a computer 102 which connects to one or more devices or instruments. The computer 102 comprises a CPU, a display screen, memory, and one or more input devices such as a mouse or  
15 keyboard as shown. The computer 102 connects through the one or more devices to a process or device 150 to perform an automation function, such as MMI (Man Machine Interface), SCADA (Supervisory Control and Data Acquisition), portable or distributed data acquisition, process control, advanced analysis, or other control.

The one or more devices may include a data acquisition board 114 and associated  
20 signal conditioning circuitry 124, a PXI instrument 118, a video device 132 and associated image acquisition card 134, a motion control device 136 and associated motion control interface card 138, a fieldbus device 170 and associated fieldbus interface card 172, a PLC (Programmable Logic Controller) 176, a serial instrument 182 and associated serial interface card 184, or a distributed data acquisition system, such as the Fieldpoint system  
25 available from National Instruments, among other types of devices.

The DAQ card 114, the PXI chassis 118, the video device 132, and the image acquisition card 136 are preferably connected to the computer 102 as described above. The serial instrument 182 is coupled to the computer 102 through a serial interface card 184, or through a serial port, such as an RS-232 port, provided by the computer 102. The PLC 176

couple to the computer 102 through a serial port, Ethernet port, or a proprietary interface. The fieldbus interface card 172 is preferably comprised in the computer 102 and interfaces through a fieldbus network to one or more fieldbus devices. Each of the DAQ card 114, the serial card 184, the fieldbus card 172, the image acquisition card 134, and the motion control card 138 are typically plugged in to an I/O slot in the computer 102 as described above. However, these cards 114, 184, 172, 134, and 138 are shown external to computer 102 for illustrative purposes. In typical industrial automation systems a device will not be present of each interface type, and in fact many systems may only have one or more devices of a single interface type, such as only PLCs. The devices are coupled to the device or process 150.

Referring again to Figures 4A and 4B, the computer system 102 preferably includes a memory medium on which software according to one embodiment of the present invention is stored. For example, the memory medium may store a reader program and/or a writer program which include GUI elements that were automatically configured to subscribe to data from a data source and/or publish data to a data target, as described herein. As another example, in one embodiment the memory medium may store "DataSocket" software as well as other software that enables a GUI element to subscribe to data from a data source and/or publish data to a data target in response to a URL. Also, the memory medium may store an application development environment which utilizes the methods described herein to support the creation and/or execution of reader/writer programs having automatically configured GUI elements.

The term "memory medium" is intended to include an installation medium, e.g., a CD-ROM, floppy disks 104, or tape device, a computer system memory or random access memory such as DRAM, SRAM, EDO RAM, etc., or a non-volatile memory such as a magnetic media, e.g., a hard drive, or optical storage. The memory medium may comprise other types of memory as well, or combinations thereof.

In addition, the memory medium may be located in a first computer in which the programs are executed, or may be located in a second different computer which connects to

the first computer over a network, such as the Internet. In the latter instance, the second computer may provide the program instructions to the first computer for execution. Also, the computer system 102 may take various forms, including a personal computer system, mainframe computer system, workstation, network appliance, Internet appliance, personal digital assistant (PDA), television system, embedded computer, or other device. In general, the term "computer system" can be broadly defined to encompass any device having at least one processor which executes instructions from a memory medium.

#### Figure 5 - Computer System Block Diagram

Figure 5 is an exemplary block diagram of the computer systems illustrated in Figures 4A and 4B. It is noted that any type of computer system configuration or architecture can be used as desired, and Figure 5 illustrates a representative PC embodiment. It is also noted that the computer system may be a general purpose computer system as shown in Figures 4A and 4B, a computer implemented on a VXI card installed in a VXI chassis, a computer implemented on a PXI card installed in a PXI chassis, or other types of embodiments. The elements of a computer not necessary to understand the present invention have been omitted for simplicity.

The computer 102 includes at least one processor or central processing unit or CPU 160 which is coupled to a processor or host bus 162. The CPU 160 may be any of various types, including an x86 processor, e.g., a Pentium class, a PowerPC processor, a CPU from the SPARC family of RISC processors, as well as others. Main memory 166 is coupled to the host bus 162 by means of memory controller 164.

The main memory 166 may store software according to one embodiment of the present invention, such as a reader and/or a writer program, and/or an application development environment operable to create the reader/writer programs. The main memory 166 also stores operating system software as well as the software for operation of the computer system, as well known to those skilled in the art. The computer programs of the present invention will be discussed in more detail below.

The host bus 162 is coupled to an expansion or input/output bus 170 by means of a bus controller 168 or bus bridge logic. The expansion bus 170 is preferably the PCI (Peripheral Component Interconnect) expansion bus, although other bus types can be used. The expansion bus 170 includes slots for various devices such as the data acquisition board 114 (of Figure 4A), a GPIB interface card 122 which provides a GPIB bus interface to the GPIB instrument 112 (of Figure 4A), and a VXI or MXI bus card 186 coupled to the VXI chassis 116 for receiving VXI instruments. The computer 102 further comprises a video display subsystem 180 and hard drive 182 coupled to the expansion bus 170.

Figure 6 – Program with a GUI Element Configured to Subscribe to a Data Source

Figure 6 is a flowchart diagram illustrating one embodiment of a method for creating and executing a program including a GUI element configured to receive data from a data source and indicate the data to the user. The developer of the program can easily and quickly configure the GUI element to receive various types of data from various types of data sources and display the data, and this configuration preferably does not require the developer to program the functionality of receiving and displaying the data. For example, the developer preferably does not have to specify or write any source code to implement this functionality.

In step 200, a GUI element may be displayed in response to user input received during program development, e.g., for inclusion on a graphical user interface for the program. A developer may include the GUI element in the program user interface in any of various ways, e.g., depending on the techniques supported by a particular application development environment for creating a graphical user interface. For example, many application development environments provide a user interface editor enabling the user to create a graphical user interface panel and place various GUI elements on the panel.

The developer may display a GUI element of any of various types, e.g., depending on what types are supported by an application development environment. For example,

various application development environments may support GUI elements such as graphs, text boxes, check boxes, knobs, etc. The application development environment may also enable the developer to create or use custom GUI elements. For example, some application development environments enable developers to use custom GUI elements packaged as  
5 ActiveX controls.

In some cases, the developer may desire to include an output GUI element in the program user interface, for example, to display data received from a data source external to the program. In other cases, the developer may desire to include an input GUI element in the program user interface, for example, to not only display the data received from the  
10 data source, but to also provide the data as input to other parts of the program.

The GUI element may be operable to display or indicate data to the user in various ways. For example, Figure 1 illustrates a chart GUI element operable to display a two-dimensional chart of data. Figure 2 illustrates GUI elements that indicate data in other ways. For example, Figure 2 illustrates a thermometer GUI element that indicates numeric  
15 data by adjusting the height of a red column, an LED GUI element that indicates Boolean data by displaying a light turned on or off, a meter GUI element that indicates numeric data by adjusting the position of a needle, etc. If a custom GUI element is used, such as an ActiveX control, the GUI element may define its own behavior for indicating data to the user. In addition to displaying data to the user, various GUI elements may also indicate  
20 data in other ways, e.g., by sending audio signals to a sound device. A GUI element may indicate discrete or continuous data. For example, in Figure 1, the chart display may change continuously as new data is constantly received, while in Figure 2, the LED light may change only occasionally, e.g., to indicate a Boolean change in the state of a variable that occurs only occasionally.

25 In step 202, user input may be received during development of the program, wherein the user input specifies a data source with which to associate the GUI element. Receiving this user input specifying the data source preferably does not include receiving user input specifying source code for the program. In other words, the developer can

specify a data source with which to associate the GUI element without having to specify any source code.

In response to the user input specifying the data source received in step 202, the method may operate to automatically or programmatically configure the GUI element to receive and display data from the specified data source in step 204. In other words, the program may be configured to connect to the data source and receive data from the data source during program execution and display the data in the GUI element. The implementation of step 204 may depend on the particular application development environment or programming language being used. In one embodiment, no source code is added to the program in performing this configuration. For example, the method may store information regarding the data source connection in a data structure. When the program is compiled, for example, the compiler may use this connection information to enable the program to dynamically connect to the data source and provide data received from the data source to the GUI element. For example, the program may launch a separate thread to perform this task. In another embodiment, the method may automatically alter the program source code in order to enable the GUI element to receive and display the data from the data source. For example, the method may automatically generate a set of functions to connect to the data source, receive data from the data source, and pass the data to the GUI element.

In one embodiment, performing step 204 may utilize a separate layer or component specialized for exchanging data with various types of data sources and targets. One such component, referred to as a “DataSocket”, is described in the above-incorporated patent application titled, “DataSocket System and Method for Accessing Data Sources Using URLs”. An overview of the DataSocket system is also given below.

In step 206, the program may be executed.

In step 208, the graphical user interface of the program may be displayed, in response to execution of the program. For example, depending on a particular language or development environment, the program may include source code for displaying the GUI, or the GUI may be automatically displayed when the program is executed. In step 208, the GUI element configured in steps 200 – 204 may be displayed on the GUI.

In step 210, the GUI element may receive data from the data source specified in step 202. As described above with reference to step 204, the program may be operable to connect to the data source and pass data to the GUI element in various ways.

In step 212, the GUI element may indicate the data received in step 210, e.g., by displaying the data or by altering the way in which the GUI element is displayed. The GUI element may indicate the data in any of various ways. For example: a chart GUI element that receives a continuous stream of numeric data may display a scrolling chart of the data; a knob GUI element that receives a numeric value may alter the appearance of the knob to illustrate that the knob is currently set to the received value; an LED GUI element that receives a Boolean value may alter the appearance of the LED light to appear to be turned on or off; etc.

Depending on the type of data source, steps 210 and 212 may be performed multiple times, as indicated by the flowchart arrow from step 212 to step 210. For example, if the data source is a DataSocket server, the program may maintain a continuous network connection with the DataSocket server and may periodically or continuously receive new data from the DataSocket server and pass the new data to the GUI element for display. For other types of data sources, such as a file, steps 210 and 212 may only be performed once.

## Figure 7 – Specifying a Data Source

Figure 7 is a flowchart diagram illustrating one embodiment of step 202. As shown in step 250, the developer may invoke a user interface dialog box for specifying data connection information for the GUI element. For example, in Figure 8 the developer has displayed a popup menu by right-clicking on a chart GUI element. By choosing the “DataSocket Connection...” menu option, the dialog box illustrated in Figure 9 is invoked.

In step 252, the developer may specify a type of data connection for the GUI element. For example, in one embodiment, the developer may specify a data connection type of “Publish”, “Subscribe”, or “Publish and Subscribe”, as shown in Figure 9. To configure the GUI element to receive and indicate data from a data source, the developer

may choose the “Subscribe” option. The “Publish” and “Publish and Subscribe” options are discussed below.

In step 254, the developer may specify the data source to associate the GUI element with. For example, Figure 9 illustrates a “Connect To:” field in which the user may provide a URL referencing the data source. In the preferred embodiment, various types of data sources may be specified. For example, the developer may specify a server as the data source, such as a HyperText Transfer Protocol (HTTP) server, a File Transfer Protocol (FTP) server, an OLE for Process Control (OPC) server, a Simple Network Management Protocol (SNMP) server, or a type of server referred to herein as a DataSocket server (discussed below). The developer may also specify a file as the data source.

The data source URL may specify the type of data source the GUI element is associated with and/or may specify a protocol to use in obtaining data from the data source. As described below, when the program is executed, the program may interface with the data source using an appropriate protocol in order to enable the GUI element to receive data from the data source. For example, a URL beginning with “ftp://” designates an FTP server. In this case, the program may interface with the data source using the File Transfer Protocol, e.g., in order to enable the GUI element to receive and display data from a remote file. Various examples of data source types are discussed below.

In step 256, the developer may apply the information specified in the dialog box, e.g., by clicking on the “Change” button shown in Figure 9.

Figure 7 represents one embodiment of step 202, and this step may be performed in various other ways. For example, in one embodiment the user may configure a GUI element by dragging and dropping an icon representing a URL onto the GUI element, wherein the URL references a data source or target.

#### Programmatically Determining an Appropriate GUI Element Based on a Data Source

It is noted that in an alternative embodiment, instead of first displaying the GUI element and then associating the GUI element with a data source, the developer may first



specify the data source, and an appropriate GUI element may be automatically included in the program's graphical user interface and associated with the data source.

In various embodiments the data source information may be provided in any of various ways. For example, many programming environments include a user interface editor or window for designing a graphical user interface. The developer may interact with the user interface editor window to specify the data source. For example, the developer may drag and drop an icon representing the data source, such as a URL icon or file icon, onto the window, or the developer may paste in data source information, e.g., a URL, from the clipboard.

In response to receiving the URL or other information, the method may operate to present the developer with a user interface, e.g., a user interface dialog such as described above, for providing further information. A URL by itself may not designate the referenced resource as either a data source or target. Thus, the dialog may enable the developer to specify whether to treat the referenced resource as a data source or a data target.

It is noted that the data source information may be received in any of various other ways, in addition to dropping or pasting the information into a window. For example, the developer may invoke a menu command that displays the above-described user interface dialog, and the developer may type or paste a URL into a text field in the dialog box and specify that the URL references a data source.

Any of various techniques may be used in automatically determining an appropriate GUI element for subscribing to data received from a data source. If the data source is a server (or is located on a server), the method may automatically connect to the server and receive data from the server. The appropriate GUI element to include in the program's GUI may then be determined based on the data received. Any of various types of data may be associated with a data source, such as strings, scalars, Booleans, waveforms, etc.

As well known in the art, the beginning portion of a URL specifies an access protocol. For example, the URL "http://www.ni.com/map.htm" specifies the hypertext

transfer protocol (HTTP) as an access protocol. In one embodiment, a data source/target may be accessed using a protocol that supports self-describing data. One example of such a protocol, the DataSocket Transport Protocol (DSTP) is discussed below. The DSTP protocol is used when interfacing with a type of server described herein, referred to  
5 as a DataSocket server. As an example, the data source URL may be a URL such as “dstp://dsserver.ni.com/wave”, and data received from this data source (i.e., received from the DataSocket server when accessing this data source) may be two-dimensional waveform data. For example, the data may comprise live waveform data that is generated in real time. Since the data is received in a self-describing format, the method may  
10 determine that an appropriate GUI element for displaying the data would be a chart GUI element.

In some cases, more than one GUI element may be operable to display the data received from a data source. Thus, in one embodiment, the method may present the program developer with a list of items or icons corresponding to the possible GUI  
15 elements, and the developer may select which one to use. Alternatively, the method may select one of the GUI elements to use, without receiving user input. For example, the selection of default GUI elements to use for various types of data may be user-configurable.

In some cases it may not be possible to determine an appropriate GUI element by  
20 examining data received from the data source. For example, the access protocol used may not support self-describing data. In this case, it may be possible to determine an appropriate GUI element based on other information. For example, if the URL specifies a file name, the GUI element may be determined based on the file extension. For example, if the URL specifies a file such as “ftp://ftp.ni.com/wave1.wav” then the  
25 method may determine that the data is waveform data, based on the “.wav” file extension. Thus, a chart GUI element may be used to display this waveform data, and/or an audio GUI element may be used which causes the “.wav” file to be audibly presented on a speaker of the computer system.

If it is not possible to automatically determine an appropriate GUI element, then the method may prompt for user input. For example, the method may display a user interface dialog or window enabling the developer to easily select which GUI element to associate with the specified data source.

5 In one embodiment, once a GUI element has been automatically determined and included in the program's graphical user interface, the developer may be allowed to easily change the GUI element to a new type of GUI element. For example, if a first GUI element was automatically determined and included in the GUI, the developer may override this choice by changing the first GUI element to a new type of GUI element,  
10 e.g., by right-clicking on the first GUI element and selecting a popup menu item to change the type.

In one embodiment, the decision of which GUI element to include in the program's GUI may be deferred until the program is executed, or the GUI element may be changed to a new type during program execution. For example, it may not be possible  
15 to connect to a data source during program development. Also, the type of data associated with the data source could change from development time to runtime. Thus, in these cases it may be desirable to examine the data at runtime and select an appropriate GUI element dynamically.

20

Figure 10 – Program with a GUI Element Configured to Publish to a Data Target

Figure 10 is a flowchart diagram illustrating one embodiment of a method for creating and executing a program including a GUI element configured to publish data to a data target.

25 In step 220, a GUI element may be displayed in response to user input received during program development, e.g., for inclusion on a graphical user interface for the program. Step 220 is similar to step 200, described above.

In some cases, the developer may desire to include an output GUI element in the program user interface, for example, to receive and display data dynamically generated

by the program during program execution. In other cases, the developer may desire to include an input GUI element in the program user interface, for example, to receive user input. In either case, a data target may be associated with the GUI element, and the program may be automatically configured to publish data associated with the GUI element (e.g., user input data or programmatically generated data) to the data target, as described below.

In step 222, user input may be received during development of the program, wherein the user input specifies a data target with which to associate the GUI element displayed in step 220. Step 222 is similar to step 202, described above. Similarly as for step 202, receiving this user input specifying the data target preferably does not include receiving user input specifying source code for the program. In other words, the developer can specify a data target with which to associate the GUI element without having to specify any source code. In one embodiment, step 222 may be performed similarly as described above with reference to the flowchart of Figure 7. However, in step 252 the developer may choose a “Publish” option for the data connection type instead of a “Subscribe” option. Figure 11 illustrates an exemplary dialog box similar to the dialog box of Figure 9. However, in Figure 11, the developer has chosen the “Publish” option instead of the “Subscribe” option, since the GUI element is being configured to publish data to a data target. A data target may be specified by a URL, similarly as for a data source.

In step 224, the method may operate to automatically or programmatically configure the GUI element to write data to the specified data target. In other words, the program may be configured to connect to the data target and write data associated with the GUI element to the data target during program execution. The implementation of step 224 may depend on the particular application development environment or programming language being used. In one embodiment, no source code is added to the program in performing this configuration. For example, the method may store information regarding the data target connection in a data structure. When the program is compiled, for example, the compiler may use this connection information to enable the program to dynamically connect to the data target and write the GUI element data to the data target. For example, the program

may launch a separate thread to perform this task. In another embodiment, the method may automatically alter the program source code in order to enable the GUI element data to be written to the data target. For example, the method may automatically generate a set of functions to connect to the data target, obtain data from the GUI element, and write the data to the data target.

In one embodiment, performing step 224 may utilize a separate layer or component specialized for exchanging data with various types of data sources and targets. One example of such a layer, which utilizes a component referred to as a “DataSocket”, is described below.

In step 226, the program may be executed.

In step 228, the graphical user interface of the program may be displayed, in response to execution of the program. For example, depending on a particular language or development environment, the program may include source code for displaying the GUI, or the GUI may be automatically displayed when the program is executed. In step 228, the GUI element configured in steps 220 – 224 may be displayed on the GUI.

In step 230, data may be associated with the GUI element, e.g., during execution of the program. Any of various types of data may be associated with the GUI element, e.g., depending on the type of GUI element. For example, a text box GUI element may have text string data, whereas a knob GUI element may have a numeric value as data. The GUI element may receive this data in various ways, e.g., programmatically or as user input, as described above.

In step 232, data from the GUI element may be written to the specified data target. As described above with reference to step 224, the method may obtain the GUI element data and write the data to the data target using any of various techniques or formats appropriate for the type of data and/or GUI element. Depending on factors such as the type of data or GUI element, steps 230 and/or 232 may be performed multiple times, as indicated by the flowchart arrow looping from step 232 to step 230. For example, if the GUI element is a chart that programmatically receives and displays a stream of numeric data, the program may write data from the GUI element to the data target in a continuous stream.

In the above description, a developer may first display a GUI element and may then specify a data target with which to associate the GUI element. It is noted that in an alternative embodiment, the developer may first specify the desired data target, and the method may operate to automatically, i.e., programmatically, determine a GUI element  
5 determine a GUI element appropriate to provide data to the specified data target, e.g., based on a file extension of the data target, if applicable, or based on information in a URL referencing the data target. For example, the method may be operable to maintain or access data on which types of GUI elements were used in the past in connection with which types  
10 of data targets. In another embodiment, the method may prompt for user input specifying a GUI element to use, in response to receiving the data target information.

Figure 12 – Exchanging Data Between a Writer and Reader Program

15 Figure 12 is a flowchart diagram illustrating one embodiment of a method for exchanging data between a writer and a reader program, wherein the program developer(s) is not required to specify any source code to perform this data exchange.

In step 270, a writer program may be created, wherein the writer program includes a GUI element configured to publish data to a server, e.g., a server program or process. For example, the GUI element of the writer program may be configured as described above with  
20 reference to Figure 10, e.g., by specifying a URL of the server and configuring the GUI element to publish data associated with the GUI element to this URL.

In step 272, a reader program may be created, wherein the reader program includes a GUI element configured to subscribe to data from the server. For example, the GUI  
25 element of the reader program may be configured as described above with reference to Figure 6, e.g., by specifying a URL of the server and configuring the GUI element to subscribe to data referenced by this URL.

In step 274, the writer and reader programs may be executed. The writer and reader programs may execute on the same computer or on different computers, e.g., computers

connected via a network. The server program may execute on one of these computers or may execute on a different computer.

In step 276, the GUI element of the reader program displays (or otherwise indicates) data from the writer program. The exchange of data from the writer program to the reader program via the server program may be implemented in various ways. One embodiment of this is described below.

Figure 12 illustrates one embodiment of a method for exchanging data between a writer and a reader program. As noted above, it is not necessary to use a reader program having a GUI element configured to subscribe to data together with a writer program having a GUI element configured to publish data. For example, the writer or reader program may not have a graphical user interface, or a writer or reader program may interact with a data target/source such as a file.

#### 15 Figures 13 – 14: Example

Figures 13 and 14 illustrate graphical user interface panels for a writer program and a reader program, respectively. Each GUI panel includes a chart GUI element configured with a data connection as described above. The chart in the Figure 13 writer program GUI panel is configured with a data connection to publish data to a data target. The chart in the Figure 14 reader program GUI panel is configured with a data connection to subscribe to data from this data target. For example, the chart GUI element of the writer program may be configured according to the dialog box illustrated in Figure 11, and the chart GUI element of the reader program may be configured according to the dialog box illustrated in Figure 9. As shown in Figures 9 and 11, the data target of the writer program and the data source of the reader program are the same. In this case, the data source/target is a DataSocket server. The programs interface with the DataSocket server using a protocol referred to as the DataSocket Transfer Protocol (DSTP), which is indicated by the “dstp://” portion of the URLs.

Figures 13 and 14 illustrate a snapshot of the two GUI panels during program execution. The writer program is operable to generate a continuous stream of numeric waveform data and display this stream of waveform data in the chart. As the chart receives and displays the data, the data is also published to the DataSocket server. The writer and  
5 reader programs may execute on different computers, and the DataSocket server may execute on one of these computers or on a different computer.

The reader program may be operable to determine that new data was written to the DataSocket server in any of various ways. In one embodiment, the reader program connects to the DataSocket server when the GUI is displayed and receives new data as the  
10 data is written to the DataSocket server, e.g., via a DataSocket component that interfaces with the DataSocket server. The reader program may then provide the data for display in the chart GUI element of the reader program. In other embodiments, the coordination of data exchange between the writer and reader programs may be implemented in any of various other ways.

As described above, the developer may configure the writer and reader programs to  
15 exchange and display live data very easily, e.g., using simple dialog boxes, without specifying any source code. The writer and reader programs may be implemented using any of various programming languages or application development environments. Figures 15 and 16 illustrate an embodiment in which the writer and reader programs, respectively,  
20 are graphical programs created using the LabVIEW graphical programming environment.

Graphical programming has become a popular programming paradigm, especially among scientists and engineers. In creating a graphical program, a developer may include a plurality of graphical nodes and other graphical elements on block diagram and connect the nodes and elements such that the resulting diagram graphically represents the functionality  
25 of the graphical program. Many users find graphical programming to be a more intuitive and user friendly model for developing a program, e.g., as opposed to using a traditional text-based programming language, such as C, C++, Basic, etc. Thus, one embodiment of the present invention further enhances the user-friendliness of graphical programming by



enabling a developer to easily configure a data connection for a GUI element on a graphical program's graphical user interface panel.

Figure 15 illustrates one embodiment of a graphical program block diagram corresponding to the reader program GUI panel illustrated in Figure 14. In this example, the block diagram includes a node labeled "Waveform Graph" that represents the chart GUI element of Figure 14. This node may be automatically included in the block diagram when the developer creates the chart GUI element. The graphical program of Figure 15 is operable to receive data written to the server by the writer program and display the data in the chart GUI element. However, the chart GUI element node is not connected to any other elements in the block diagram, illustrating that the developer did not need to specify any graphical source code for the block diagram to enable the chart GUI element to receive and display the desired data.

In addition to the chart GUI element node, the reader program block diagram of Figure 15 also includes a programmatic loop element 500. When the program executes, the graphical code inside the loop is executed until the user presses the "Stop" button shown on the Figure 14 GUI panel. As described above, the writer program is operable to write a continuous stream of numeric waveform data to the server. Thus, the programmatic loop enables the reader program to execute indefinitely. While the reader program executes, the data is received from the server and displayed in the chart GUI element. As discussed above, for example, a separate thread may be responsible for handling the exchange and display of this data.

In one embodiment, the graphical programming environment may be operable to automatically generate graphical code such as the programmatic loop element 500 and the graphical code inside the loop. For example, the developer may create the chart GUI element and configure the chart GUI element with a data connection to subscribe to the server. The developer may then request the graphical programming environment to automatically generate code such as the loop code shown in Figure 15. This would allow the developer to create an entire program to receive and display live data continuously from a data source, without having to specify any source code for the program at all. This may

be useful, for example, to enable users to quickly connect to various data sources and monitor data, with no programming involved. For example, a user may easily monitor real-time measurement data acquired by an instrument located in a remote laboratory.

Figure 16 illustrates one embodiment of a graphical program block diagram corresponding to the writer program GUI panel illustrated in Figure 13. Similarly as described above, the block diagram includes a node labeled “Waveform” that represents the chart GUI element of Figure 13. In this case, the chart GUI element node is connected to another node in the block diagram. However, this connection is for providing waveform data generated by the Cosine Wave function node to the chart GUI element. The block diagram does not include any graphical source code for writing the chart GUI element data to the server. As described above, this data connection information may be specified via a user interface, e.g., via a dialog box, without the developer specifying graphical source code to implement this functionality.

In the examples of Figures 15 and 16, the program may implement the connection from a GUI element to a data target or source “behind the scenes” of the block diagram. In other words, source code indicating this connection does not appear on the block diagram. In another embodiment, it may be desirable to include source code indicating the connection on the block diagram. In this case, the source code implementing the data connection may be automatically included on the block diagram when the developer specifies the data connection information. For example, Figure 17 illustrates another embodiment of a graphical program block diagram corresponding to the reader program GUI panel illustrated in Figure 14. In this embodiment, the chart GUI element node is connected to another node, unlike the diagram of Figure 15. The chart GUI element node receives data from a DataSocket node 510. This DataSocket node is configured to connect and read data from the DataSocket server referenced by the URL, “dstp://dssserver.ni.com/wave”. Thus, in this embodiment, the user can view source code implementing the data connection to the data source.



shown, the user may also choose to browse measurement data. For example, in one embodiment, the user may be able to subscribe to a hardware device as a data source or publish data to a hardware device data target. Figure 19 illustrates a dialog box that may appear when the user selects “Browse Measurement data”. This dialog box displays various data sources and targets associated with hardware instruments connected to the computer.

The dialog box of Figure 19 also lists OPC servers available to the host computer. OPC (Object Linking and Embedding (OLE) for Process Control) is built on Microsoft ActiveX and Distributed Component Object Model (DCOM) technology. OPC servers and clients exchange real-time information among a variety of systems. OPC establishes an open industry standard for plug-and-play interoperability among disparate automation devices, systems, and software.

The user can configure a GUI element to connect to an OPC Server in the same way as any other data source. A URL identifies the OPC server item. URLs that address OPC servers start with opc: and include the following parts:

- //machine\_name [optional]—Identifies the computer on which the OPC server is installed.
- /server\_name—Specifies the OPC server to connect to.
- /item\_name—Specifies the OPC item on the specific OPC server.
- UpdateRate = n [optional]—Specifies in milliseconds how often the OPC server should check the device for new values.
- DeadBand = n [optional]—Specifies what percentage change is required before the server notifies your application of a value change.

The following is an example of a URL that reference the National Instruments OPC test server installed with the LabVIEW application:

`opc://machine.ni.com/National Instruments.OPCTest/item1?UpdateRate=1000&DeadBand=10`

As described in the above-incorporated U.S. Patent Application No. 09/374,740, titled “System and Method for Automatically Creating URLs for Accessing Data Sources

and Data Targets”, in one embodiment, URLs for accessing data sources and targets may be automatically generated. Various hardware devices, hardware device channels, OPC servers, etc., may be referenced by these URLs. Thus, when a user selects a data source or target associated with a hardware device from the dialog box of Figure 19, the “Connect To” field of Figure 18 may be populated with a URL corresponding to the data source or target. The URL may include configuration information for a device. Thus, when a program having a GUI element configured with a data connection to a hardware device data source or target executes, the device may be automatically configured.

Figure 20 illustrates an alternative embodiment of a dialog box for specifying data connection information. As shown in Figure 20, the dialog box may include a “Protocol” control allowing the user to specify a protocol to use, such as “HTTP”, “FTP”, etc. Other fields in the dialog box may change appropriately, depending on the selected protocol. For example, in Figure 20 the user selected the FTP protocol, and the dialog box displays fields for entering a username and password for connecting to the FTP server.

Figure 20 also illustrates a “Test Connection” button. This may enable the user to interactively test the connection to a data source or target, before program execution. For example, this may help to detect any errors in the specified hostname or path of a data source or target, any network connection problems, etc.

#### Connection Status and Data Type Issues

In one embodiment, the status of a data connection for a GUI element may be visually indicated on the GUI panel. For example, as shown in Figure 21, a small status indicator 520 may appear beside a GUI element when a data connection for the GUI element has been specified. If the connection is valid, this indicator may be colored green during program execution, or if not, the indicator may be colored red.

An invalid connection may be caused by an error in a specified hostname or path of a data source or target, a network connection problem, etc. Also, an invalid connection may

occur when a GUI element is not compatible with its configured data source or target. For example, a program may be able to connect to a data source and receive data from the data source, but the data received may not be valid data for the GUI element.

Any of various types of data may be associated with a data source, such as strings, scalars, Booleans, waveforms, etc. A given GUI element may only be operable to display certain types of data. For example, a chart GUI element may be able to display two-dimensional numeric waveform data, but not three-dimensional waveform data. In this case, if three-dimensional waveform data is received from a data source with which the chart GUI element is associated, an invalid connection may be indicated. As described below, in one embodiment, data may be received in a self-describing format enabling the program (or execution environment) to parse the data appropriately and determine whether the data is valid data for a particular GUI element.

In one embodiment, if the data is not valid data for the GUI element, then the program or execution environment may be operable to dynamically select a GUI element that is valid for the data, i.e., a GUI element that can receive and display the data. This GUI element may then be dynamically substituted for the original GUI element at execution time.

#### Figures 22 – 23: Three Dimensional Waveform Example

Figures 22 – 23 illustrate GUI panels for a writer program and reader program, respectively. The writer and reader program operate similarly as the writer and reader programs of Figures 13 and 14 described above. However, in this case the writer program displays and writes 3D waveform data to a server and the reader program receives and displays this 3D data. Also, Figures 22 and 23 illustrate the use of custom GUI elements. In these programs the data is displayed using a custom ActiveX control operable to display 3D waveform data.

Figure 24 – Live Weather Data Example

Figure 24 illustrates a GUI panel for a program operable to receive and display live weather data, such as wind speed data, temperature data, humidity data, etc. Any or all of the GUI elements shown on the GUI panel may be configured to receive data from a data source, such as data generated by a program executing on a remote computer. For example, in Figure 24, the developer has selected the “Wind Speed (mph)” gauge GUI element and displayed a popup menu. As described above, the developer may invoke a dialog box via this menu for specifying a data connection for the Wind Speed gauge GUI element.

As described below, one embodiment of the present invention enables multiple reader programs to receive and display data generated by a writer program, by interfacing with a server. Thus, multiple users may execute the program of Figure 24 to view live weather data. In the prior art, creating these types of applications is typically a complicated task, but one embodiment of the present invention enables data exchange between a writer program and multiple reader programs executing in different locations to occur without the developer having to supply any source code.

Figure 25: Two-Way Exchange of Data

In the examples discussed above, a GUI element was configured to either publish data to a data target or subscribe to data from a data source. In some cases, it is desirable for a program to both receive data for display in a GUI element from external data sources and provide data associated with a GUI element to external data targets. Figure 25 is a flowchart diagram illustrating one embodiment of a method for performing this type of two-way data exchange by configuring a GUI element to publish and subscribe to a data target/source. The method of Figure 25 illustrates an example in which two-way exchange of data is performed in order to coordinate the monitoring and control of a remote system. However, the ability to configure a GUI element to both publish and subscribe to data may be useful in many other situations.

In step 300, two programs may be executed, e.g., at different locations, in order to monitor and control a remote system. Each program may have a GUI control configured to both publish and subscribe to data. For example, the programs may display a knob GUI control, such as the Frequency knob shown in the GUI of Figure 1, configured to publish and subscribe to data. For example, consider a situation in which two control programs execute at different locations, wherein users of the control programs monitor a remote system and control the opening and closing of a valve in the remote system by turning the knob GUI control.

In step 302, the GUI control for each program may display a value indicating a setting for the system. In the example above, the knob GUI controls may display a value indicating the current state of the valve on the remote system.

In step 304, a user of one of the control programs, i.e., the “first” control program, may specify a new value for the GUI control displayed by the first control program. In the example above, the user may turn the knob GUI control of the first control program to a new value.

In step 306, the first computer program may adjust the system according to the new value. In the above example, the first computer program may adjust the remote system by sending a control signal requesting the remote system to open or close the valve controlled by the knob GUI control. Also, since the GUI control is configured to publish its data, the new value is published to the configured data target/source to which the GUI control of the first control program is configured to publish and subscribe. For example, the new value may be published to a server as described above.

The other control program, i.e., the “second” control program, may also subscribe and publish to this data source/target. Thus, in step 308, the second control program may receive the new value published by the first control program, e.g., by interfacing with the server, and may update the value displayed by the GUI control of the second control program. In the example above, the knob GUI element of the second control program may thus be automatically turned to reflect the new setting specified by the user of the first control program.



### DataSocket System

As discussed above, a program with a GUI element configured with a data  
5 connection to a data source or target may utilize a separate layer or component for  
interfacing with the data source or target. This section provides an overview of one  
embodiment of such a layer, referred to as "DataSocket". For more information on the  
DataSocket system, please refer to the DataSocket documentation available from  
National Instruments Corp. or to the above-incorporated patent application titled,  
10 "DataSocket System and Method for Accessing Data Sources Using URLs".

DataSocket provides a single, unified, end-user application programming interface  
(API) for connecting to data from a number of sources, such as local files, files on FTP or  
Web servers, and data items on OPC Servers. A DataSocket application specifies the  
15 data location by using a familiar networking standard, the URL. Just as a Web browser  
uses a URL to connect to a Web page, a DataSocket application uses a URL to connect to  
data. By using an industry-standard URL, the user can quickly and easily bring data into  
or share data from DataSocket applications. In addition, the DataSocket Transfer  
Protocol connects a DataSocket application to live data by specifying a connection to a  
20 DataSocket Server. The DataSocket Server manages most of the networking tasks for the  
user.

With the DataSocket Server, a lightweight, stand-alone component, programs  
using DataSocket can broadcast live data, such as measurement data, at high rates across  
a network such as the Internet to multiple remote clients concurrently. These client  
25 applications use DataSocket to subscribe to the live data. Because the DataSocket Server  
is a stand-alone component, it simplifies network (TCP/IP) programming by  
automatically managing connections to clients and automatically converting data to and  
from the stream of bytes sent across the network. The user does not have to write the  
parsing code. The DataSocket Server can run on any computer on a network, which

improves performance and provides security by isolating the Web connections from other applications.

Various DataSocket APIs are provided so that various types of programming environments may interface with a DataSocket Server for data exchange. For example, as shown in Figure 17, a DataSocket node may be included in the block diagram of a graphical program. An ActiveX DataSocket interface is also provided, enabling C++, Basic, Java, and other types of programs to use DataSocket.

With conventional technologies such as TCP/IP, the developer would have to write code to convert data to an unstructured stream of bytes in the broadcasting application, as well as code to parse the stream of bytes back into its original form in subscribing applications. DataSocket, however, transfers data in a self-describing format that can represent data in an unlimited number of formats, including strings, scalars, Booleans, and waveforms. The DataSocket read and write operations transparently convert data to and from the underlying byte streams, eliminating the need to write complicated parsing code. DataSocket uses a protocol referred to as the DataSocket Transport Protocol (DSTP) to send data to and receive data from a DataSocket server.

With DataSocket the data source or target name is in the form of a URL. For example, in the URL, “dstp://localhost/wave”, the “dstp://” indicates that the DataSocket application is connecting to a DataSocket Server using the DataSocket Transfer Protocol for live data. The “localhost” indicates that the DataSocket Server is running on the local machine; if the DataSocket Server were running on another machine, the user would replace localhost with the machine name or IP address. The “wave” is the data item name on the server. This is an arbitrary name which identifies the location of the data on the DataSocket Server. A single DataSocket Server can handle numerous data items.

#### Figure 26 – DataSocket Server

Figure 26 illustrates an example of a DataSocket server receiving data from a single writer application and providing the data to a plurality of reader applications. For example,

the GUI chart elements shown in the writer and reader applications may be configured to publish data to and receive data from the DataSocket server. In the preferred embodiment, the DataSocket server by default allows multiple read (client) connections to a specific data item, but only one write connection. Thus, a developer may easily create an application in which a writer application distributes data to a plurality of clients, without having to specify source code to perform this data distribution. In the prior art, creating these types of applications is typically a complicated task.

Using the DataSocket server, the writer supplying the data is not required to handle the administrative details of sending data to many different clients, and hence can run more efficiently. The DataSocket server, which can be located on a different machine, assumes the task of redistributing the information. The user can configure the maximum number of data items and maximum number of connections allowed to the server. The user can also configure multiple write connections to a data item at the same time, if desired.

15

#### Figure 27 – DataSocket Transfer Protocol

A brief description of the DataSocket Transfer Protocol as used in one embodiment follows:

20

#### Message Formats :

Messages may be made up of packets of bytes comprising the following parts.

1. [message\_length] A 4-byte integer field (in little-endian) describes the length of the entire message in bytes, including the 4-byte header.
- 25 2. [message\_format] A 2-byte enumeration that describes the binary format of the data in the message\_data field. Types include 1,2,4,8 byte integers, 4 & 8 byte floating-point numbers, ASCII and UNICODE strings. There are two special enumeration values. The first, "array", is followed by a nested message whose type field describes the array element type. The second special enumeration value "cluster" is followed by a two byte

count and then by series of nested messages each describing one element of data that follows in the message\_data section.

3. [message\_data] Optional data in the format identified by the second field. In the case of arrays and clusters, there may be more than one value.

5

#### Message Types :

##### Kinds of messages:

Messages are sent as a block of values stored in the "cluster" format described above. The first element is the op code, subsequent elements are parameters, if necessary, for the specific op code.

10

1. Greeting exchange, protocol version exchange.
2. Request from client to subscribe to an item maintained by the server. Items are identified by a ASCII or UNICODE string.
3. Request from client to server to cancel any existing subscription on an item
- 15 4. Request from client to server to get an item's value
5. Request from client to server to set an item's value
6. Notification from server to client of an item's value. This may be in response to a subscription or a specific request for the value.
7. Notification from server to the client that the served is being shut down.
- 20 8. Notification from client to server that it is closing the connection. (This implies canceling any subscriptions made on the connection.)

#### Message opcodes :

##### Opcodes used:

25

kCWDS\_Connect,  
kCWDS\_Disconnect,  
kCWDS\_SetVersion,  
kCWDS\_Logon,  
kCWDS\_Subscribe,

kCWDS\_Unsubscribe,  
kCWDS\_SetValue,  
kCWDS\_GetValue,

5 Message Sequences :

Sequences:

With the exception of the greeting messages, the client, or server never waits for a reply. Either the client or server can cancel the session at any time by sending the appropriate "disconnect" message.

10

Protocol functions :

Functions:

Getting, setting, and subscribing to values of items stored in a database maintained by a server.

15

Name of the port :

nati-dstp

20

DataSocket handles all tasks of converting data and data attributes from their native application format (strings, arrays, Booleans, etc.) into a TCP/IP suitable format, referred to as the Flex Data format, and converting back from the Flex Data format on the client end. Because the DSTP network communication only requires TCP/IP support, the DataSocket can be used to share information through many different types of networks, including the Internet. The DataSocket can be used to share information between machines located on opposite sides of the world using local Internet service providers. Of course, DataSocket and the DataSocket server can be used on a local Windows network or in a single stand-alone computer.

25

### Figures 28A - 28B: Connect Method Flowchart Diagram

Figures 28A – 28B are a flowchart diagram illustrating the Connect method of a DataSocket according to one embodiment. It is noted that various steps in Figures 28A – 28B may occur concurrently and/or in different orders. Also, Figures 28A – 28B illustrate one embodiment of the DataSocket, but the DataSocket system and method may be implemented in various ways, or data may be exchanged using other techniques besides DataSocket.

As shown in step 402 the DataSocket may receive a request to connect to the specified URL. For example, the developer may have created a program with a GUI element configured to connect to a data source or target specified by the URL. When the program begins execution, the program may attempt to connect to the data source or target, e.g., by requesting the DataSocket to connect to the URL.

In step 404 the DataSocket partitions the URL into an AccessMethod, Host, and Path. The AccessMethod of the URL preferably comprises the first portion of the URL, e.g., http, ftp, file, dstp, etc. Other AccessMethods are also contemplated. The “Host” portion specifies the host computer where the data is located, and the “Path” specifies the path where the data is located on the host computer.

If the AccessMethod is either http or ftp as determined in step 410, then in step 412 the DataSocket connects to the http or ftp server using conventional technology, e.g., using conventional Internet technology.

After step 412, in step 414 the DataSocket determines the file type. The DataSocket determines the file type for http based on the mime type. The DataSocket may also determine the file type based on the URL path suffix and/or the stream contents.

After step 414, operation proceeds to step 442.

If the access method is “file” as determined in step 420, then in step 422 the DataSocket opens the file using the system’s file library. In step 424 the DataSocket determines the file type based on the file suffix, the file contents, or parameters contained within the URL. After step 424, operation advances to step 442.

After the DataSocket has determined the file type in either of steps 414 or 424, in step 442 the DataSocket determines if it has built-in support for the type. If the DataSocket has built-in support for the file type as determined in step 442, then in step 444 the built-in adapter comprised in the DataSocket converts the data from the file or stream into a Flex Data object, also referred to as a FlexDataObject.

In step 444 the DataSocket converts the data into a form more usable by a typical programming language or application. Examples of data converted by the DataSocket include WAV files, tabbed text files, DSD files, and text. For example, if the data is retrieved from a spreadsheet, the DataSocket converts the tab delimited spreadsheet data into a 2D array of numbers, without any tabs or ASCII strings. This 2D array of numbers is not required to be parsed by the containing application. Also, in general, a number of engineering formats exist for storing vectors or arrays. The DataSocket preferably operates to convert data of these various formats into arrays of data or numbers for direct use by the application. After step 444, operation proceeds to step 460.

In step 460 the Flex Data object value in the DataSocket is set. This means that the data which was converted into the more usable form in step 444, such as a 2d array, is now stored in memory managed by an object that is accessible by the client program. The client application may get a copy value from the Flex Data object by calling a method on the Flex Data object named "GetValue". This method preferably returns a copy of the value stored in a VARIANT, a structure defined by Microsoft as part of its ActiveX standard for component software. The Value of attributes can be gotten by calling a method named GetAttribute, or set by calling a method called SetAttribute. A VARIANT structure is used for attributes as well. The VARIANT structure can hold simple data types like numbers or Boolean values and data types that require additional memory for storage such as strings and arrays.

In step 462 the DataSocket notifies the container or application using the DataSocket that it has received a value from the data source, preferably through a new data event. Operation then completes.

If the DataSocket does not include built-in support for the file type as determined in step 442, then in step 446 the DataSocket determines if a DataSocket file adapter is registered for that file type. A DataSocket file adapter is created by a user and registered with the DataSocket. The DataSocket file adapter is used to read or write files using custom-defined formats. If a DataSocket file adapter is not registered for that type, then in step 490 the DataSocket notifies the container or application that the value cannot be retrieved, and operation completes.

If a DataSocket file adapter is registered for that file type as determined in step 446, then in step 452 the DataSocket creates the file adapter component or client. In step 454 the DataSocket calls or invokes the file adapter's Connect method. In step 456 the file adapter reads data from the file identified by the URL. In step 458 the file adapter constructs a Flex Data object with values and attributes extracted from the file.

After steps 452 - 458 have been performed, in step 460 Flex Data object value in the DataSocket is set, and in step 462 the DataSocket notifies the container or application that it has received a value from the URL, and operation completes.

If the access method is "dstp" as determined in step 430, then in step 432 the DataSocket attempts to make a connection to the DataSocket server identified by the URL using the host name or Internet address encoded in the URL according to standard URL syntax. As described above, the access mode "dstp" directs the DataSocket to connect to the DataSocket server identified in the URL. If the connection is established in step 432, then in step 434 the DataSocket sends a command indicating a request to subscribe to a specific tag or item, or to write the value of a specific tag maintained by the DataSocket server. The DataSocket preferably sends this command over TCP/IP. If the specific tag does not exist on the server, then the server may create the tag and give it an initial value, or may report back an error indicating that the requested tag does not exist. This is a configuration option on the DataSocket server. Reporting errors is preferably done by sending commands over the TCP/IP connection. Commands are preferably sequences of bytes sent over a TCP/IP connection.



After step 434, as updates are received in step 436, the DataSocket sets the value in the DataSocket's Flex Data object and notifies the container or application using the DataSocket. Thus, each time update notifications are received from the server, the Flex Data object is set and the container or application is notified of each update. Step 436 is continually performed as data is received until the container instructs the DataSocket to disconnect from the data source to which it is connected.

If the access method is not "dstp" as determined in step 430, and is not either http, ftp, or file as determined in steps 410 and 420, then in step 472 the DataSocket derives or constructs the name of an extension or plug-in from the access method that was specified in the URL. For example, if the access method is "opc" then the name of the extension or plug-in could be "DataSocketPlugIn\_opc".

In step 474 the DataSocket determines if a DataSocket extension or plug-in with that name is registered. Thus, if the access method is not one of the pre-defined types, e.g., http, ftp, file, or dstp, in steps 472 and 474 the DataSocket attempts to intelligently determine the proper extension or plug-in from the access method that was specified in the URL.

If no DataSocket plug-in is registered with the derived name, then the DataSocket notifies the application or container that the value cannot be retrieved, and operation completes.

If a DataSocket plug-in is registered for the determined extension name as determined in step 474, then steps 476 - 482 are performed.

In step 476 the DataSocket creates an extension component based on the registered DataSocket extension. In other words, the DataSocket instantiates a component from the registered DataSocket extension.

In step 478 the DataSocket calls the extension component's Connect method. In step 480 the extension or plug-in connects to the data source determined by the path and parameters in the URL. In step 482, when the data source has a value, the extension stores the value in a Flex Data object and operation then advances to 460. As discussed above, in steps 460 and 462 the DataSocket's Flex Data object value is set and the

DataSocket notifies the container that it has received a value from the data source, and operation then completes.

5     Figure 29 – Data Viewer Program

As noted above, in one embodiment, when a program receives data from a data source during program execution, an appropriate GUI element to display the data may be determined dynamically, i.e., at runtime, and the GUI element may be dynamically included in the program's graphical user interface and configured to display the received data. One  
10     embodiment of the invention comprises a program which utilizes this ability to enable end users to connect to various types of data sources and display data received from the data sources. In such a program, an end user (i.e., a user of the program, rather than the program developer) may specify a data source. The data source may be a data source of any of various types, such as a file or a server of various types, such as an HTTP server, an FTP  
15     server, an OPC server, a DataSocket server, a database server, etc. The end user may specify the data source in any of various ways. For example, the program may be operable to receive URL information specifying the data source, similarly as described above.

In response to receiving the data source information from the end user, the program may be operable to automatically determine an appropriate GUI element for displaying data  
20     from the data source, display the GUI element, and provide data from the data source to the GUI element for display. The appropriate GUI element may be determined similarly as described above, e.g., by connecting to the data source to receive a data sample from the data source and then examining the received data, or in any of various other ways. Also, in one embodiment, the program may enable the user to explicitly specify a GUI element to  
25     use in viewing the data. For example, in response to a user command, the program may display a set of GUI elements from which the user can choose.

Thus, one embodiment of the invention enables the implementation of a program which, when executed, enables an end user to specify a data source, e.g., via a URL, and view data received from the data source, wherein the end user may specify any of various

types of data sources, any of various types of data may be received from the data sources, and any of various types of GUI elements may be dynamically displayed to allow the end user to view the received data.

This latter embodiment may be utilized, for example, to implement a data viewer tool which end users may execute to view various types of live data. For example, the data viewer tool may enable end users to connect to remote instrumentation systems and view real-time data acquired or generated by the systems, including numeric data, two-dimensional waveform data, three-dimensional waveform data, etc.

Figure 29 is a flowchart diagram illustrating one embodiment of a method for enabling an end user to view various types of data from various types of data sources.

In step 600, a data viewer program is executed.

In step 602, the data viewer program may receive user input specifying a data source. The data source user input may comprise URL information, for example. Any of various types of data sources may be supported, including files of various types and servers of various types, such as described above. Also, any of various types of data may be associated with the data source.

In step 604, the data viewer program may automatically determine an appropriate GUI element for viewing data received from the data source. Step 604 may be implemented similarly as described above.

In step 606, the data viewer program may dynamically display the determined GUI element and configure the GUI element to receive and display data from the data source. Step 606 may be implemented similarly as described above.

In steps 608 and 610, the GUI element receives data from the data source and displays the data, similarly as described above.

Although the embodiments above have been described in considerable detail, numerous variations and modifications will become apparent to those skilled in the art

Figure 1 displays 12 histograms showing the distribution of the number of non-zero elements in the vector  $x$  for different values of  $n$  (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120). The x-axis is labeled 'x' and ranges from 0 to 120. The y-axis is labeled 'count' and ranges from 0 to 100. The distributions are centered around 60 and become more spread out as  $n$  increases.